SPACE for NATIONAL DEVELOPMENT

MDASat a nanosatellite constellation to improve the South African maritime domain awareness capability

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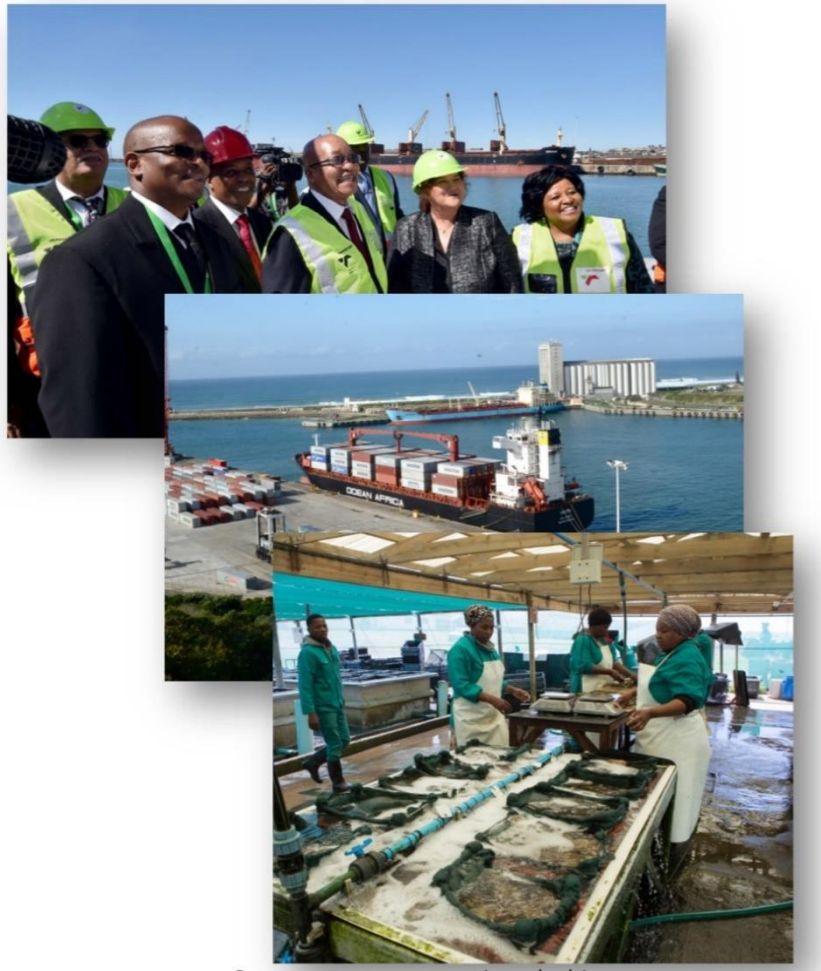
Operation Phakisa

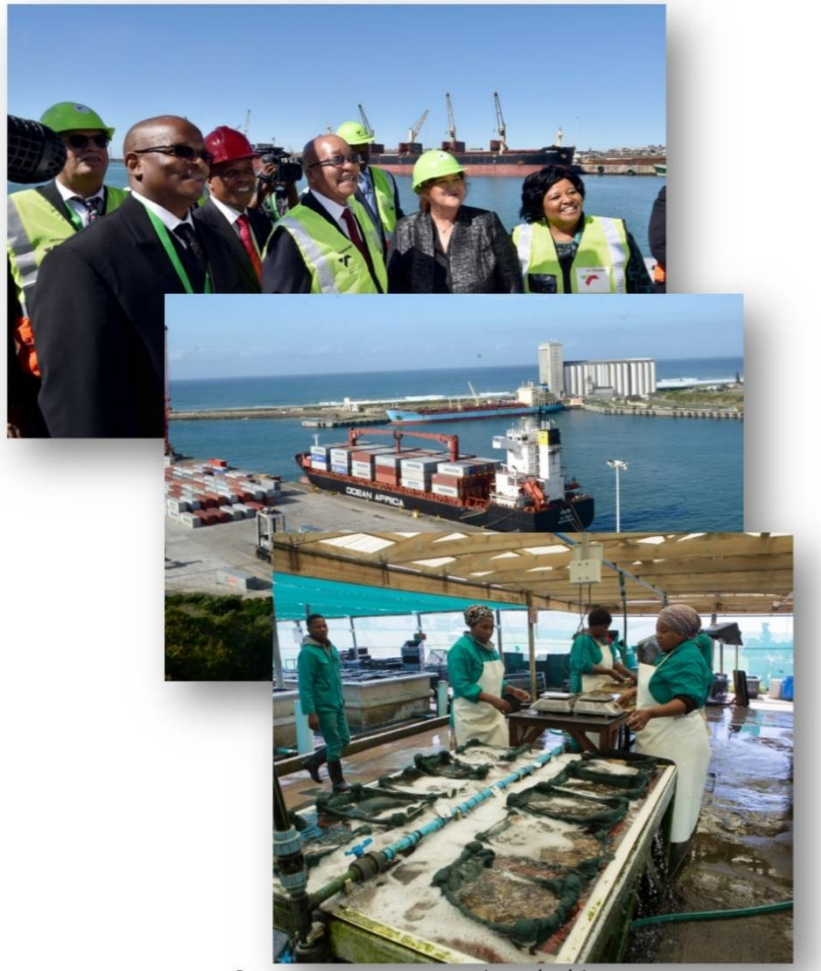
- Fast results programme: fast track implementation
- Focuses on SA's Oceans Economy: potential to grow GDP by $12 billion by 2033, and create over 1m jobs.
- Effective governance is a critical enabling factor
- Coordinated enforcement and monitoring of compliance with the law in South Africa's EEZ



Source: www.operationphakisa.gov.za

Operation Phakisa

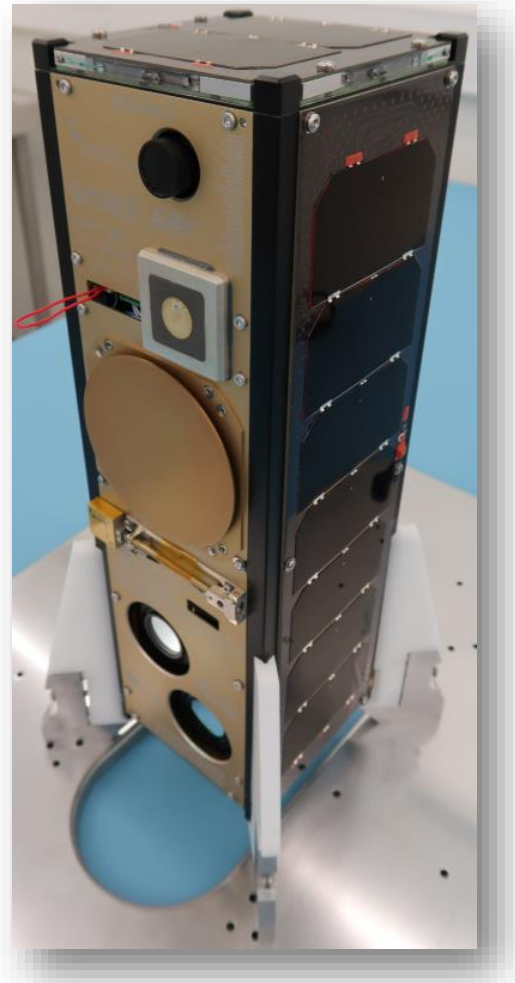
- Ten key initiatives. Initiative 6:
  - National Oceans & Coastal Information Management System (OCIMS) and extend Earth observation capabilities.
- OCIMS developed by the Council for Scientific and Industrial
  Research (CSIR). It includes:
  - Automatic Identification System (AIS) data from international data providers to track ocean traffic within the EEZ
  - Synthetic Aperture Radar (SAR) data to identify dark targets that are not emitting AIS beacons.



Source: www.operationphakisa.gov.za

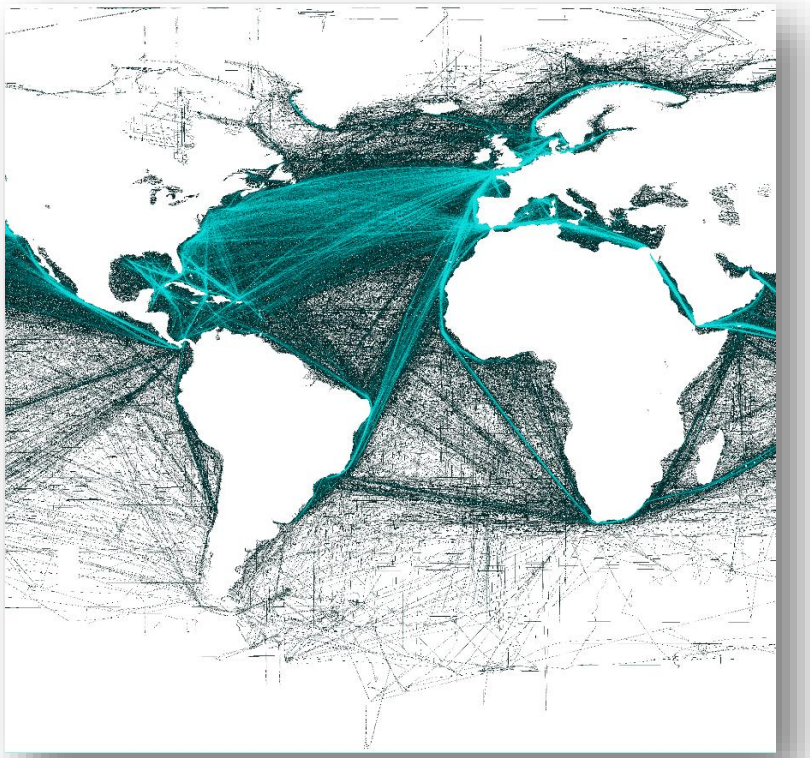
Phakisa Phase 1 | ZACube-2

- Funded by Department of Science and Innovation
- Built by graduates of F'SATI's Satellite Programme at CPUT
- Mission Objectives
  - Directly supports initiative 6 of Operation Phakisa by providing South Africa with sovereign capability to independently obtain AIS data that can be used in OCIMS
- 3U CubeSat, launched Dec 2018 into 500 km Sun-synchronous orbit
- Precursor to MDASat constellation
- 3-axis Y-momentum ADCS allows nadir pointing, pitch control in Y-axis.
- Payloads
  - Technology demonstration of AIS message reception using the primary payload
  - Technology demonstration of a medium resolution imager payload



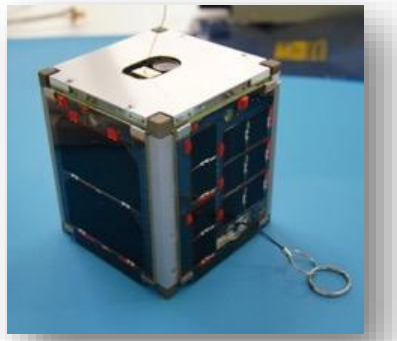
Phakisa Phase 2 | MDASat

- Builds on ZACube-2 heritage, constellation of 9 satellites to be launched in 3 phases
- First phase, MDASat-1 will consist of 3 satellites, to be launched Q4 2020
- Software defined radio (SDR) payload to receive AIS messages from ocean vessels
- Provide VDES services to maritime users
- Collection of statistical data in the South African maritime zone, with a special focus on vessel detection.

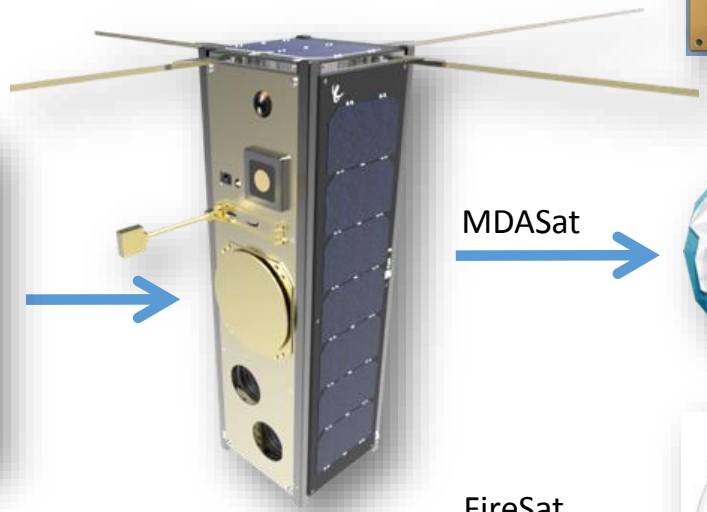


Technology Roadmap

Nanosatellite constellations under development

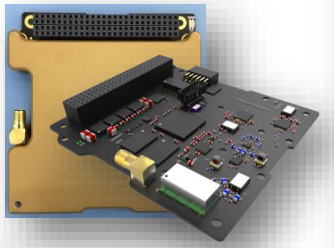


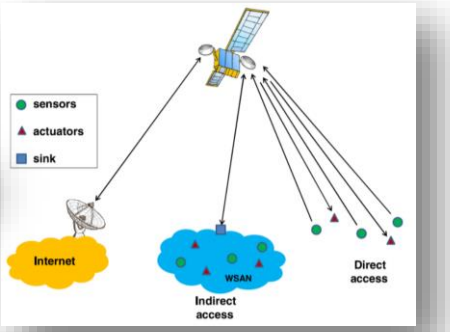
ZACUBE-1 | 2013



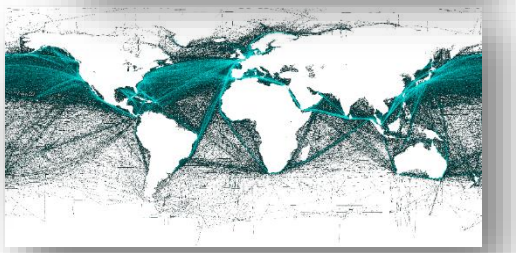
ZACUBE-2 | 2018

M2M/IoT





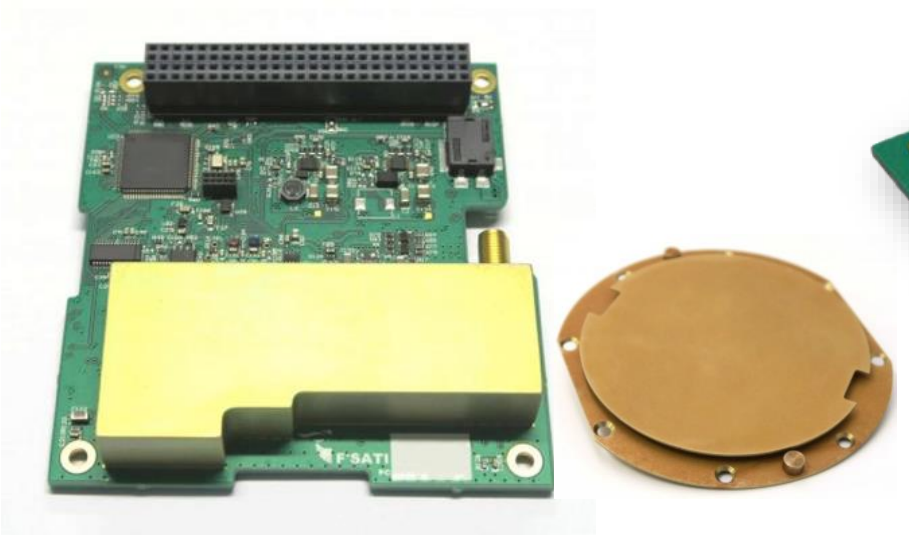
MDASat



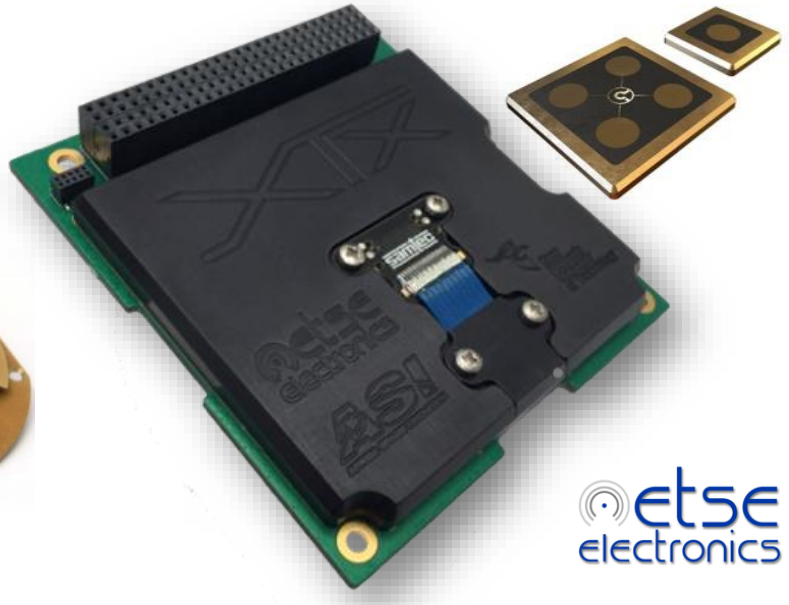
FireSat

CubeSat radio communication products

UHF/VHF and UHF/UHF Transceivers
(Amateur and commercial)



S-band Transmitter and Antenna
(Amateur and commercial)

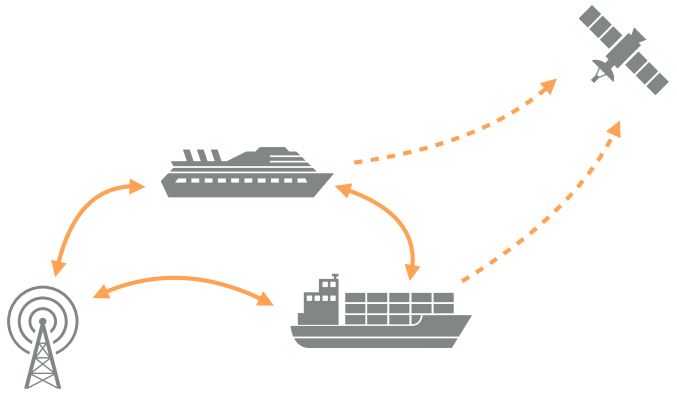


X-band Transmitter and Antenna
(Commercial)

Technology | AIS

Background and challenges

- AIS was developed for collision avoidance between vessels
- Uses two VHF channels to broadcast:
  - Vessel name, MMSI no, time, latitude, longitude, speed, direction etc.
- AIS monitoring from space became feasible although AIS was not originally designed for reception by satellite



Acknowledgment to StoneThree Comms

Technology | AIS

Background and challenges

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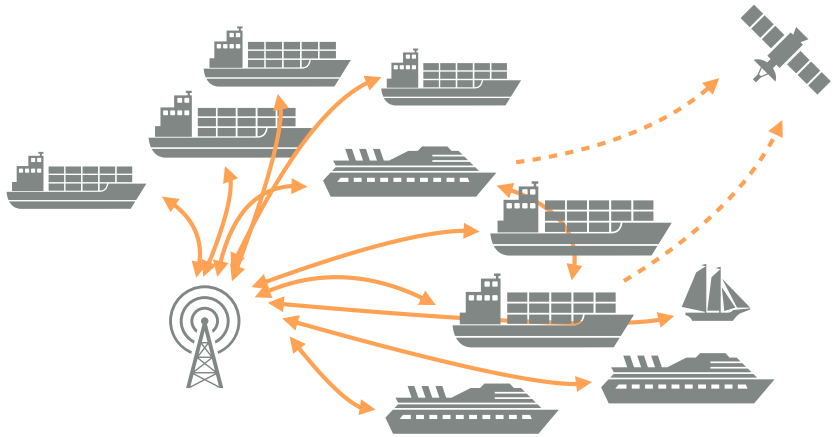
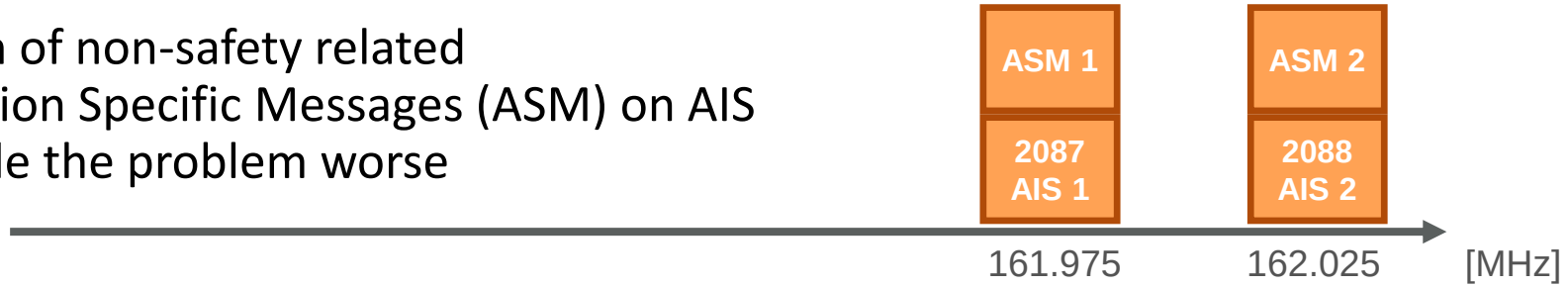
  - Vessel name, MMSI no, time, latitude, longitude, speed, direction etc.
- AIS monitoring from space became feasible although AIS was not originally designed for reception by satellite
- As service grew, AIS channels became congested
- Addition of non-safety related Application Specific Messages (ASM) on AIS has made the problem worse



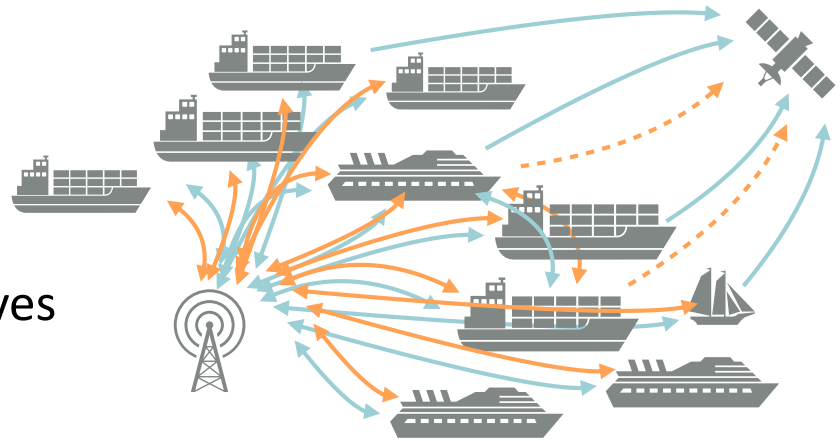


Acknowledgment to StoneThree Comms

Technology | AIS

Background and challenges

- The first step was to move ASM away from AIS to dedicated channels
- Changes to the modulation doubles the ASM data rate compared to AIS
- The addition of forward error correction (FEC) codes improves performance
- It has also been designed to specifically support satellite reception

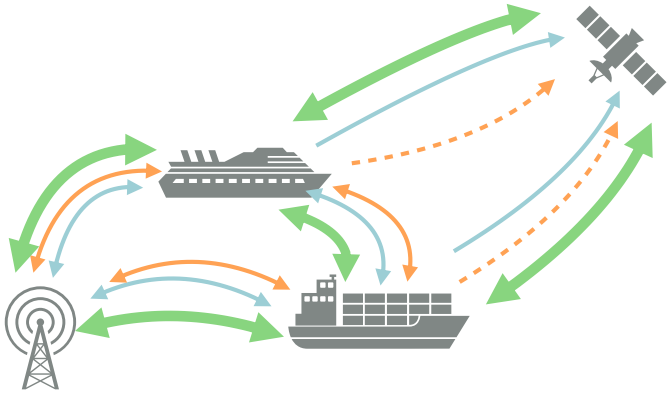


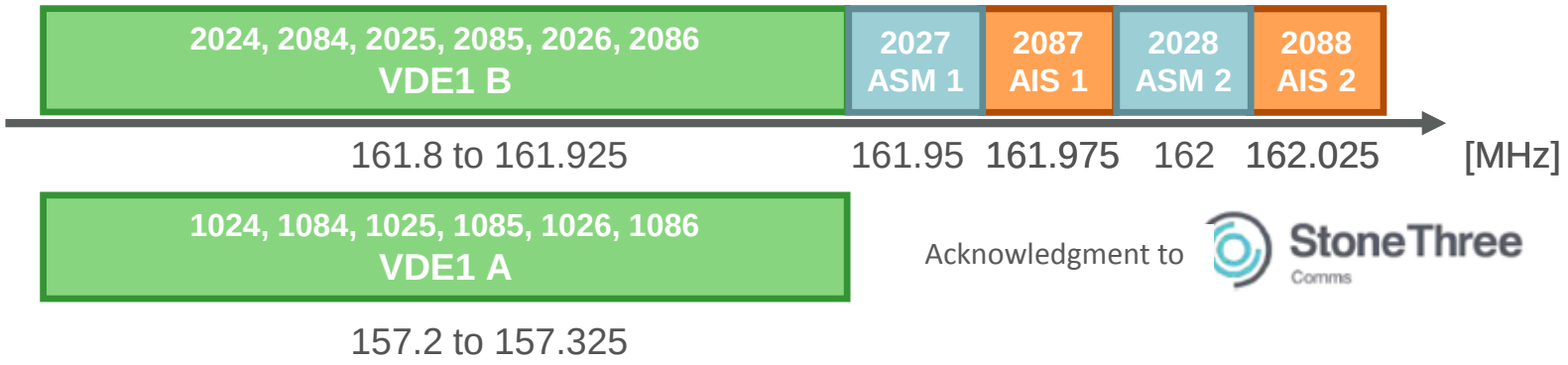
Acknowledgment to StoneThree Comms

Technology | VDES

Dedicated VHF Data Exchange channels

- To support higher BW data applications two wideband channels were allocated
- More efficient modulation and coding methods designed specifically for data transfer, VDES uses available bandwidth 8x more efficiently than existing AIS
- VDE Satellite supports an up-link throughput of up to 94kbps and a satellite downlink throughput of up to 48kbps.
- VDE satellite channels decided at WRC-19



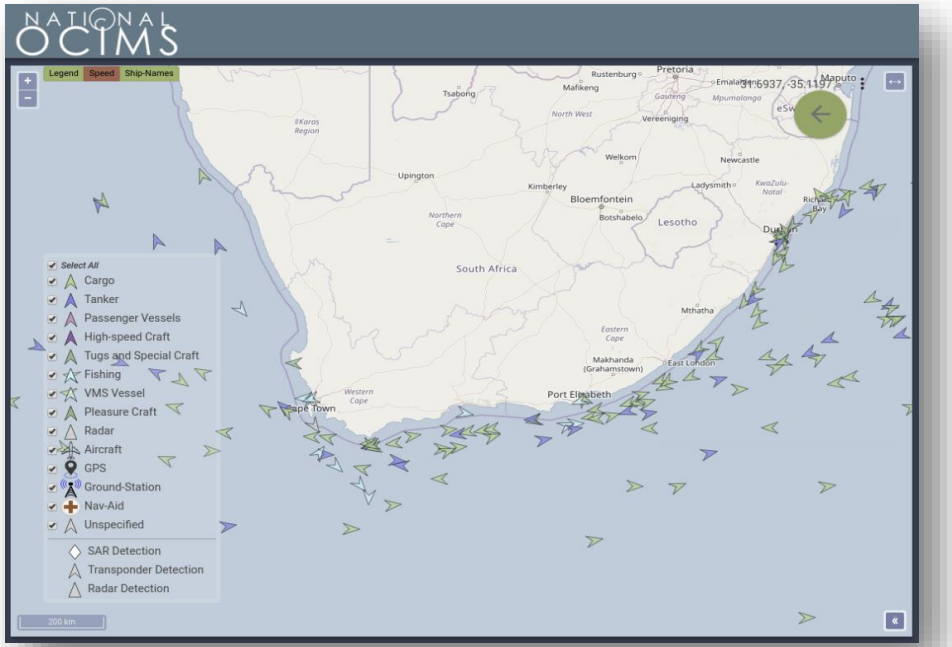


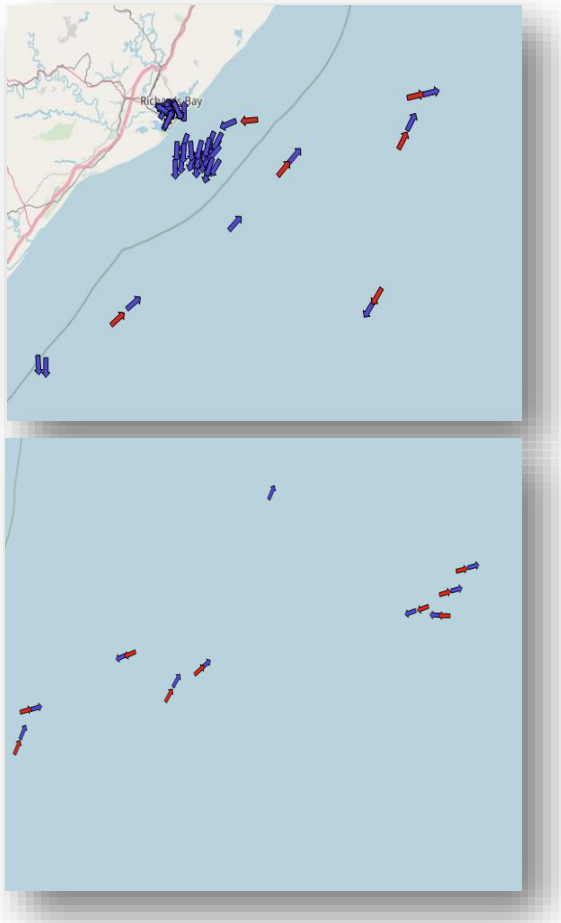
Acknowledgment to StoneThree Comms

ZACube-2 mission results

OCIMS ingestion of data and comparison with commercial data

- ZACube-2 (red arrows) performs well in low traffic areas
- Commercial data (blue) performs better in high traffic areas.
  - Possibly augmented with data from coastal AIS stations





Acknowledgment to

CSIR
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science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

sansa
SOUTH AFRICAN NATIONAL
SPACE AGENCY

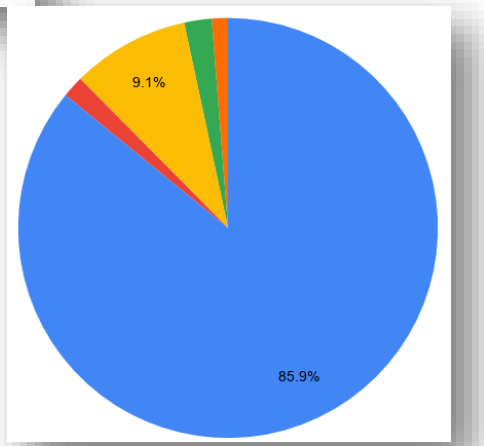
ZACube-2 mission results

AIS PAYLOAD: STATS

- SDR payload activated 23 times
- 24 400 AIS messages downloaded
- 4617 different MMSI (ship IDs) detected
- 10862 messages originated within SA EEZ
- Activations performed with satellite out of view (Australia and central Africa)
- Almost equal spread between AIS channel 1 and 2 messages
- 86% of messages are scheduled position reports

All AIS messages from 23 payload sessions

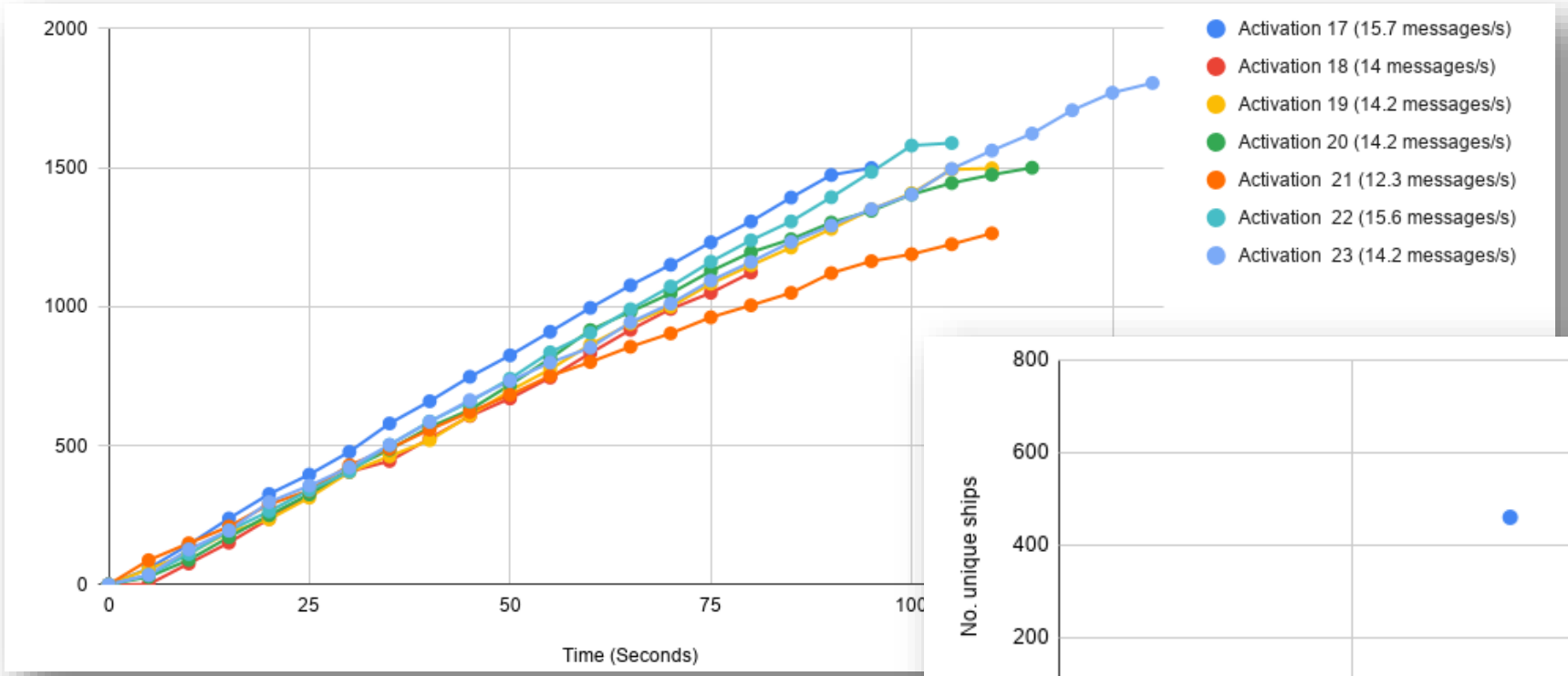
Distribution of AIS messages types received

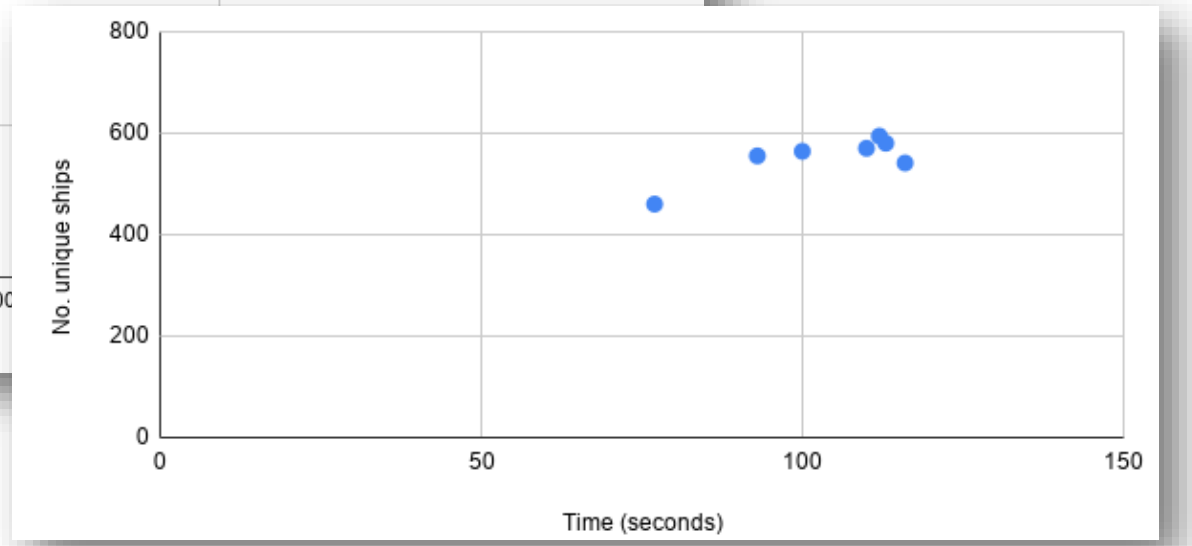


1	Position report (scheduled)
3	Position report (When interrogated)
4	Base station report
18	Standard Class B equipment position report
	Other

ZACube-2 mission results

AIS PAYLOAD: AIS message accumulation rate

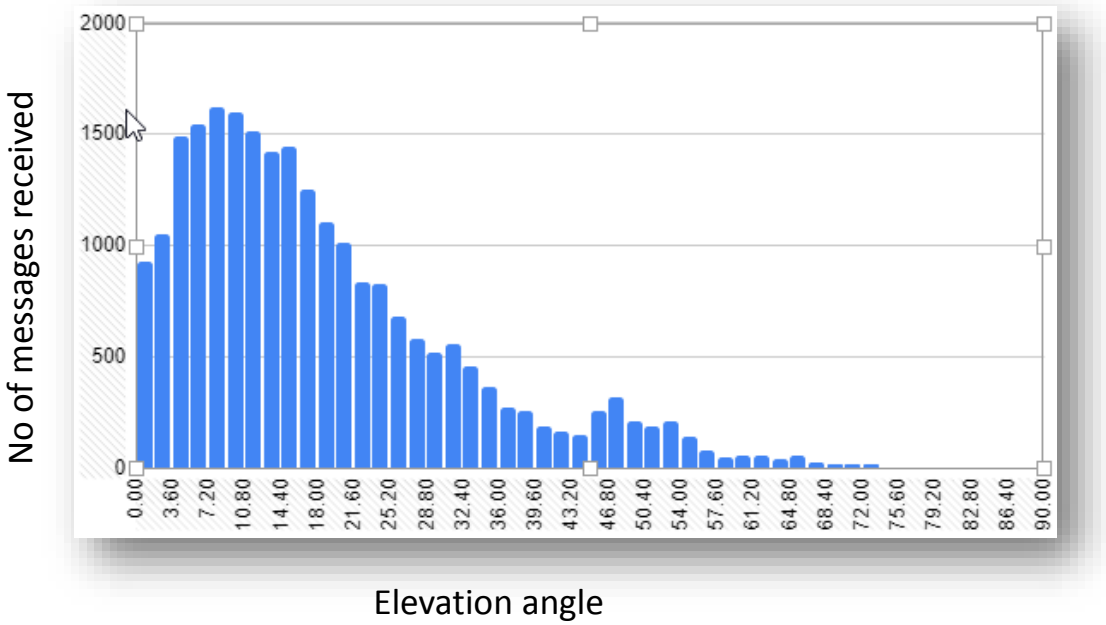




ZACube-2 mission results

AIS PAYLOAD: Communications pattern analysis

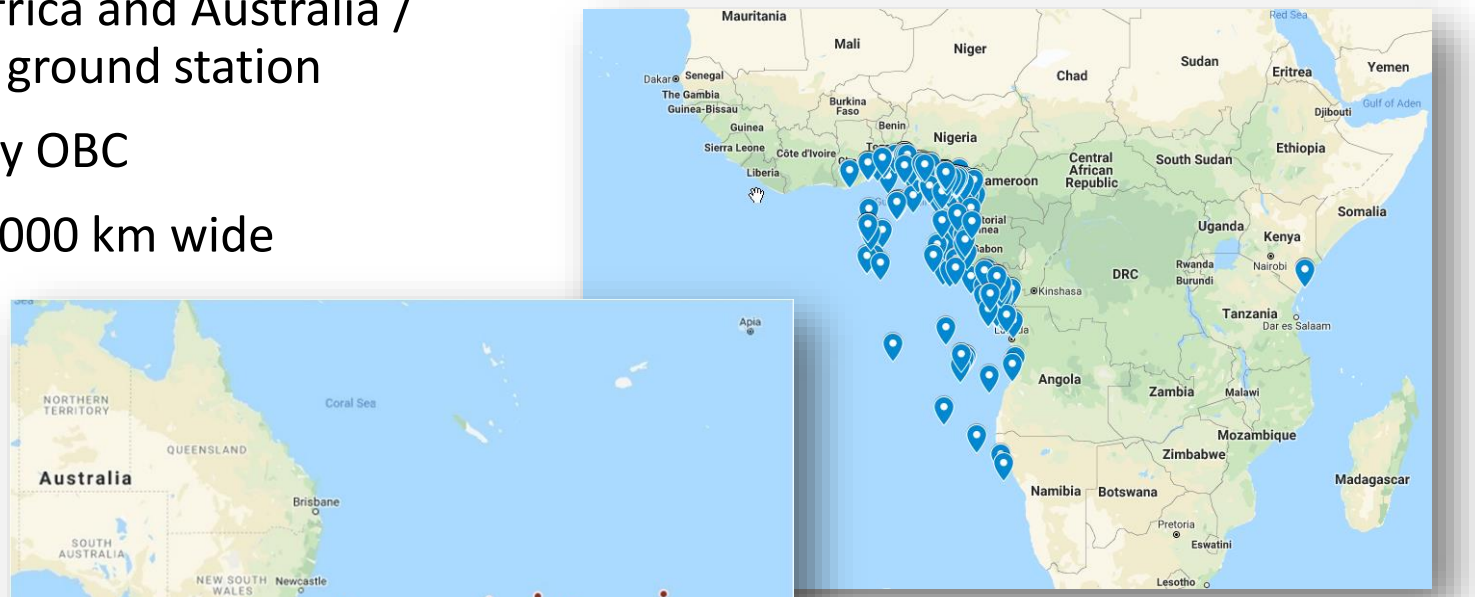
- Payload antenna
  - Deployable VHF dipole antenna
  - Aligned with satellite's Z-axis
  - Radiation pattern nulls towards nadir and zenith
- AIS beacon antennas on ships also vertically oriented
- Expect maximum gain towards horizon
- Analysis done to determine distribution of received messages with elevation angle (referenced to ocean vessel)

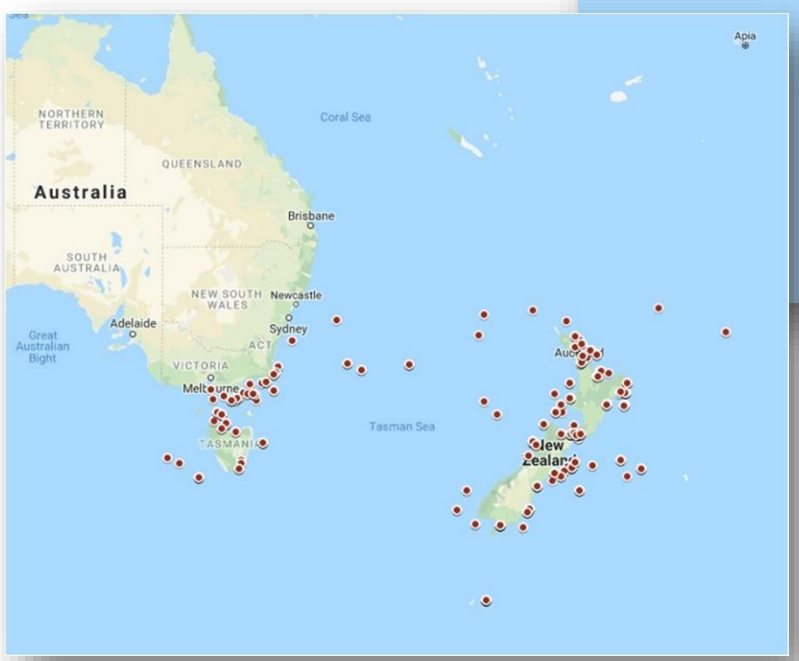


ZACube-2 mission results

AIS PAYLOAD: Scripted operation (beyond line of sight)

- Scripted operation over central Africa and Australia / New Zealand out of view of CPUT ground station
- Payload activated automatically by OBC
- Messages received over entire ~5000 km wide footprint down to horizon
- 598 messages in 42 seconds
- Demonstrates capability to receive AIS messages anywhere around the globe





MDASat-1

Payload revision compared to ZACube-2

- ZACube-2 SDR payload
  - Receives and processes only AIS channels 1 & 2
  - Does not support Over-The-Air (OTA) firmware updates
- MDASat-1 SDR payload
  - No hardware changes needed
  - Supports OTA firmware updates
  - Captures processed spectral information of raw sampled wideband data (flying spectrum analyser)
  - Captures raw data of whole channels to allow analysis of signal anomalies
  - In addition to AIS channels 1 & 2, also receives long range AIS channels 1 & 2
  - Necessary step towards full VDES support

Conclusions

- ZACube-2 achieves AIS message reception rates at 40% of channel capacity.
  - Techniques to improve message rate to be investigated
- Mission roadmap to be further expanded with MDASat-2
- Payload to be improved to support the complete VDES specification
- SDR unit to include transmitter to support Satellite VDES downlink (pending WRC-19 approval)
- Machine-to-machine communication
  - MDASat-2 to provide machine-to-machine communications services, initially based on VDES.
  - Adaptable SDR transceiver can support various distributed sensor applications, e.g. asset tracking, ADS-B (aircraft tracking), grid monitoring, precision agriculture, etc.

THANK YOU

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